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# A New All Gas-Phase Chemical Iodine Laser

**Scientists developed and demonstrated a new chemically pumped laser.**

*AFRL's Directed Energy Directorate, Laser Division, High Power Gas Lasers Branch, Kirtland AFB NM*

Solid-state lasers convert electrical energy into light using optical excitation. Although efficient, scientists continue research into scaling these devices for high-power applications. Chemical lasers efficiently convert energy derived from chemical bonds and reactions into laser photons.<sup>1</sup> Scientists use chemical lasers for applications that require high-power, lightweight, and self-contained sources of laser radiation because of their inherent high efficiency and scalability. The two classes of chemical lasers are the hydrogen fluoride (HF) laser and the chemical oxygen-iodine laser (COIL).

Despite the commercial and military need for high-power lasers, the development of new chemical laser devices is a relatively rare event. Researchers first demonstrated the HF laser in the mid-1960's.<sup>2</sup> Prior to the work reported here, the last chemical laser invented was the first COIL device, which Dr. William McDermott and co-workers demonstrated in 1978.<sup>3</sup> Since then, scientists focused most chemical laser research on advancing the COIL and HF technologies to the point where multi-kilowatt devices can be routinely constructed.

Although very efficient, high-power chemical lasers generally require the use of toxic, explosive, or otherwise hazardous chemicals. For example, COIL devices use a very corrosive chemical called basic hydrogen peroxide (BHP) and HF lasers use molecular fluorine, which is extremely corrosive and toxic. In addition to being corrosive, BHP is a liquid at room temperature. This does not preclude engineers from using a COIL in the zero-gravity environment of space, but it certainly poses significant engineering challenges. The HF laser, which uses all gas-phase chemicals, has its own limitations. HF lasers generally operate on multiple wavelengths in the 2.7-3.5  $\mu\text{m}$  region of the infrared spectrum. In addition to the challenge of producing appropriate mirrors for the laser resonator, 2.7  $\mu\text{m}$  radiation does not transmit well through the atmosphere due to water absorption. In contrast, a COIL device operates on a single wavelength (1.3  $\mu\text{m}$ ) that is not strongly absorbed by the atmosphere.

Directorate scientists developed the all gas-phase iodine laser (AGIL) to eliminate the heavy, aqueous-based COIL chemistry and the undesirable wavelength range of the HF laser. AGIL combines the excellent laser properties exhibited by COIL (single wavelength at 1.3  $\mu\text{m}$ ) with lighter

weight, all-gas phase reagents typically associated with an HF device. AGIL mixes chlorine atoms (Cl) and gaseous hydrogen azide ( $\text{HN}_3$ ) to produce an excited nitrogen chloride (NCl) molecule. Excited NCl molecules exchange energy with atomic iodine in a manner analogous with oxygen in COIL.<sup>4</sup>  $\text{HN}_3$ , a chemical cousin to sodium azide, which is used as a propellant in automotive airbags, is an extremely energetic and potentially explosive substance.

The AGIL team first demonstrated optical gain<sup>5</sup> (necessary but not sufficient to generate lasing) when they combined Cl atoms (generated by an electric discharge),  $\text{HN}_3$ , and a small flow of atomic iodine in a gas flow duct. After several series of gain optimization experiments, the AGIL team reported a low-power laser demonstration.<sup>6</sup> While the very first demonstration produced only 6 mW of laser energy, subsequent demonstrations with the same device produced 180 mW. For comparison, the first COIL demonstration<sup>3</sup> produced 10 mW.

The AGIL offers advantages over both the COIL and the HF laser. With AGIL, gases are lighter than liquids and easier to transport, maintain, and store. This is advantageous for the Airborne Laser (ABL) (see Figure 1), which will need to keep at least one of its liquid chemicals under constant refrigeration for safety reasons. If scientists can successfully scale AGIL to higher powers, it will offer the potential as an ideal laser technology for the Space-Based Laser (SBL). For space use, lasers can only use gaseous chemicals—the lack of gravity in space significantly complicates gas-liquid interactions necessary to produce the desired laser radiation in a COIL device. For this reason, the present SBL design uses an HF laser because the chemical components are gases, not liquids. However, the HF laser operates on a wavelength that is not as efficient or effective as the  $1.3 \mu\text{m}$  wavelength enjoyed by the ABL. By using AGIL, the SBL will have the advantages of a gaseous laser and COIL's more desirable  $1.3 \mu\text{m}$  wavelength.

The successful demonstration of AGIL technology represents a significant step in the development of chemical lasers. AGIL is the first continuous-wave chemical laser developed in over twenty years and the second such device invented at AFRL.

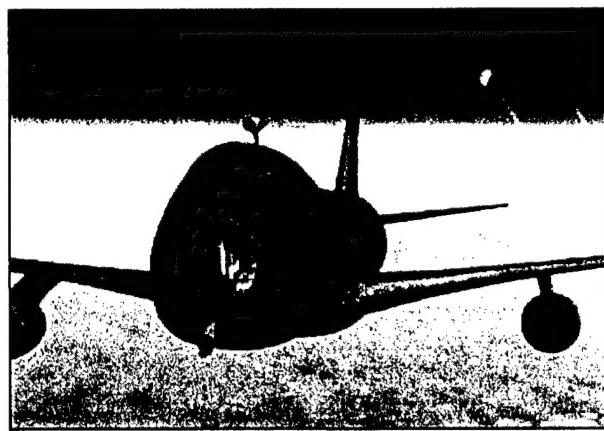


Figure 1. Conceptual drawing of the ABL system

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